(14) NRL-MR-1302

NRL MEMORANDUM REPORT 1302

(11) April 1962

(12) 9p.

(6) EFFECT OF CATHODIC PROTECTION ON LOW-CYCLE CORROSION FATIGUE OF HY-80 STEEL AT SLOW CYCLE RATES

(9) Interim rept.,

BY

(16) SR00708

(17) SR0070806

(10) J. A. SMITH,
M. H. PETERSON
~~AND~~
B. F. BROWN

PHYSICAL METALLURGY BRANCH

Approved for public release; distribution unlimited

DIST. "A"

251950

METALLURGY DIVISION

U. S. NAVAL RESEARCH LABORATORY

WASHINGTON 25, D. C.

CONTENTS

ABSTRACT

The application of cathodic protection extends the fatigue life of HY-80 in salt water, and this would be expected to be the more marked the lower the cycle rate. The intrusion of a hydrogen embrittlement phenomenon, however, precludes retention of air fatigue life in salt water by cathodic protection if the cycle rate is slow.

PROBLEM STATUS

This is an interim report. Work on this problem is continuing.

AUTHORIZATION

NRL Problem Number: 63M04-02

Bureau Problem Number: SR 007-08-06, Task 0718

DISTRIBUTION

BUSHIPS (Code 634B, Mr. R. L. Hollenbeck)...25
NRL (Code 6302)..............................10
(Code 6320)..............................10
(Code 6325)..............................10
(Code 2028).............................. 5

INTRODUCTION

Earlier studies of the effects of cathodic protection have shown that it is possible to retain most if not all of the fatigue life in air by impressing cathodic currents. Figure 1 shows typical results. For the most part these studies were concerned with stresses near the endurance limit and hence many of the experiments were liable to require 10^6 or more cycles, and high cycle rates were accordingly typical. The specimens of Fig. 1 were run at 6000 cycles per minute.

The electrochemical move required to protect iron against aqueous corrosion can be visualized in the diagram of Fig. 2. Iron in salt water at or near the neutral point is situated in the "corrosion triangle". To achieve immunity, the potential of the iron must be depressed to bring it into the domain of being cathodically protected. In doing so, however, one unavoidably crosses the broken line below which hydrogen is reduced. Now the hydrogen, when reduced, has three courses open to it: It can pass off as bubbles of molecular hydrogen, it can react with any dissolved oxygen; or it can enter the steel. If it enters the steel, it can cause embrittlement if the state of stress and strain rate are favorable. Hydrogen embrittlement phenomena are characteristically strain-rate sensitive, and it was considered necessary to make experimental studies at low cycle rates before assuming that the conclusions one might draw from Fig. 1 are applicable at the lower rates.

EXPERIMENTAL PROCEDURE

Specimens 3/32 inches thick and shaped as in Fig. 3 were machined and stressed in reverse bending in cells equipped with potential controllers of local design and manufacture (Fig. 4). Two levels of stress were investigated, one just at the yield (as estimated from a short resistance-strain gage) and one not determined but well out in the plastic region. The solution was 3-1/2% reagent grade sodium chloride in distilled water. It was found difficult to set all machines to exactly the same rate in this range of speeds, but all were operated in the range 3/4 to 1 cycle per minute; no rate sensitive effects were noted in this range. The specimens run in air were coated with oil to obviate the effects of variable humidity, which otherwise is generally observed to cause scatter in the life of specimens fatigued in air.

RESULTS

The results are shown in Fig. 5. Here it may be seen that the loss in fatigue strength caused by the presence of salt water can be partially but not completely recovered by cathodic protection. Hydrogen embrittlement effects intrude to prevent full recovery of air fatigue values. Earlier static tests on sharply notched tensile bars of the same steel, cathodically charged under sustained loading, had failed to indicate any embrittlement. In the case of very thin structures, particularly such as wire rope, one would expect the benefits of even a modicum of cathodic protection to be even more dramatic than indicated in Fig. 5. For pitting would drastically reduce the corrosion fatigue life, but as has been shown (3), a small amount of cathodic protection serves to eliminate pitting even if it is not sufficient to eliminate all corrosion.

Full retention of air fatigue life would seem to require a coating. For laboratory purposes it should be possible to move to the right in Fig. 2 and recover fatigue life without cathodic protection, and this was verified by adding 1% NaOH, with the result that the specimen had the same fatigue life as in air. The addition of K_2CrO_4 would also be expected to prolong the fatigue life in salt water.

The principal conclusions from this study will be tested on specimens approximately one-inch thick.

ACKNOWLEDGMENTS

This program is being supported by Code 634B of the Bureau of Ships (Mr. T. Griffin).

REFERENCES

1. U. R. Evans and M. T. Simnad, Proc Roy Soc, 188, 1947.

2. M. Pourbaix, "Thermodynamics of Dilute Aqueous Solutions", (Arnold, London) 1949.

3. L. J. Waldron and M. H. Peterson, Corrosion, 17:188, 1961.

FIGURE CAPTIONS

Fig. 1 - Effect of impressed currents of various magnitudes on the corrosion fatigue of steel (Reference 1).

Fig. 2 - Partial potential-pH diagram for iron (after Reference 2).

Fig. 3 - Corrosion fatigue specimen.

Fig. 4 - Schematic diagram of corrosion fatigue apparatus.

Fig. 5 - Effect of potential level on corrosion fatigue life, two stress levels.

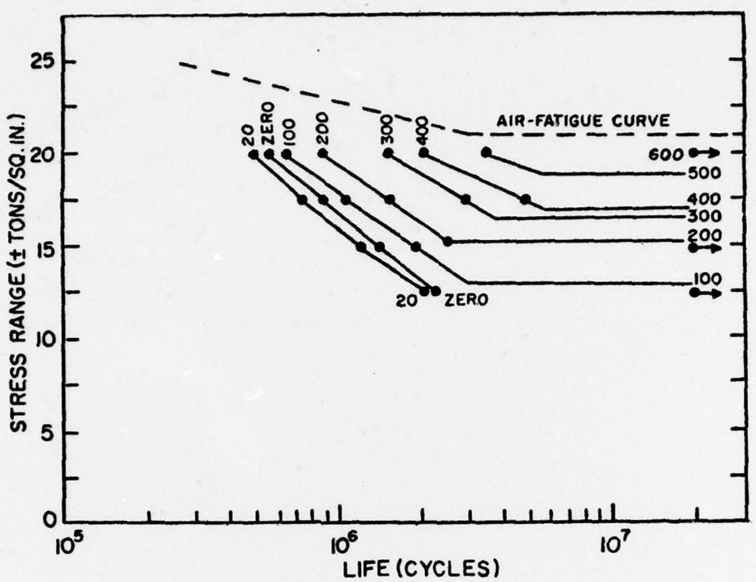

Fig. 1 - Effect of impressed currents of various magnitudes on the corrosion fatigue of steel (Reference 1)

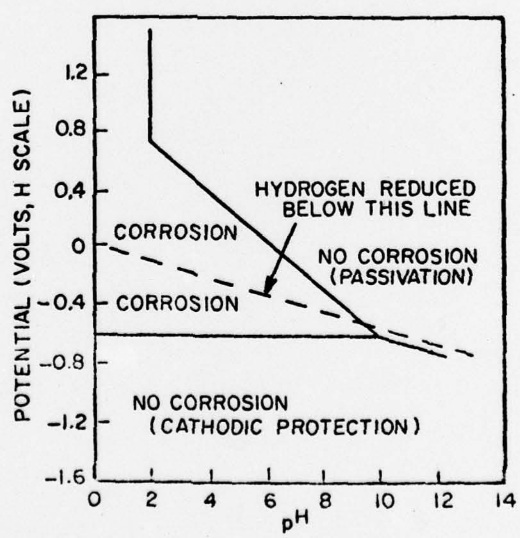

Fig. 2 - Partial potential-pH diagram for iron (after Reference 2)

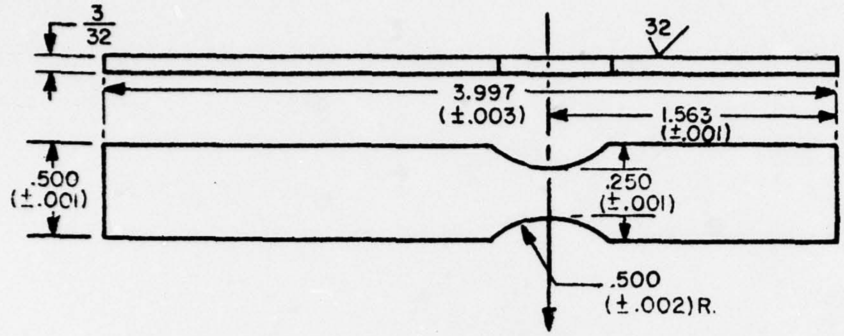

Fig. 3 - Corrosion fatigue specimen

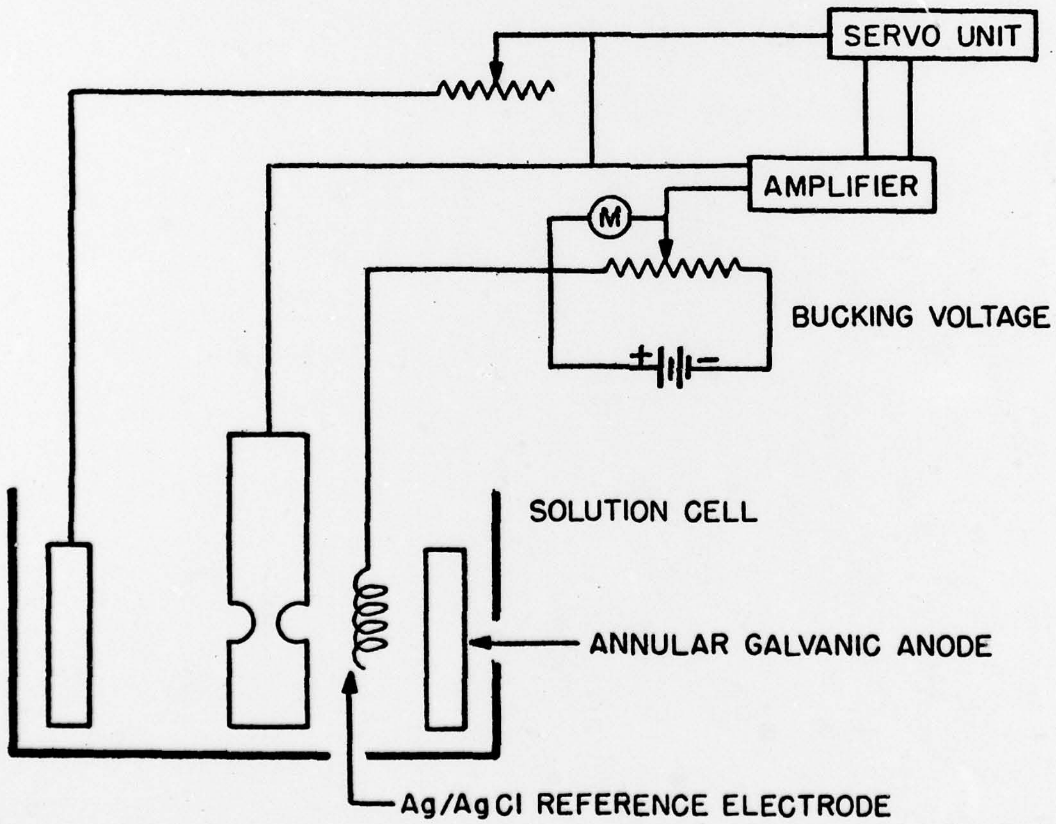

Fig. 4 - Schematic diagram of corrosion fatigue apparatus

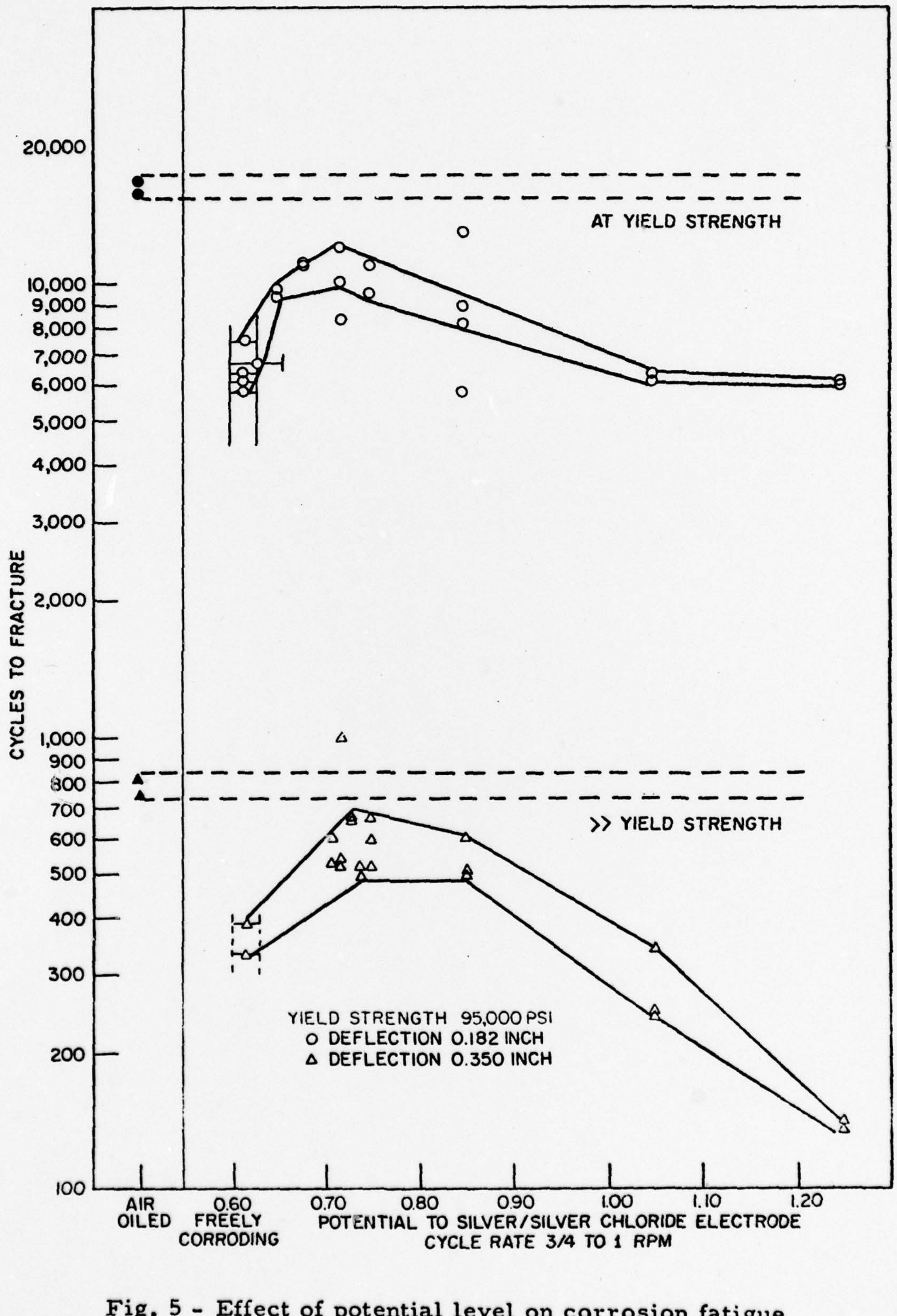

Fig. 5 - Effect of potential level on corrosion fatigue life, two stress levels